BUNDESANSTALT FÜR GEOWISSENSCHAFTEN UND ROHSTOFFE

HANNOVER

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The Palaeomagnetic Record of Selected Tasmanian Rock Units

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Date: 4. September 1991

Archiv-Nr.: 108 847

Abstract

A collaborative program of the Department of Mines and the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) was undertaken to study the feasibility of various Palaeozoic and Mesozoic rocks for palaeomagnetic analysis. The results of our palaeomagnetic measurements have shown that the vast majority of Palaeozoic Tasmanian rocks have been exposed to at least one episode of magnetic overprint. In our opinion, the most effective overprint episode occurred at the Devonian/Carboniferous time boundary. Nevertheless, in few cases the overprint component was successfully removed and an earlier (primary) component identified.

Our key results are:

The Cambrian Smithton Trough volcanics were magnetically overprinted during the early Carboniferous. In rare instances, a primary component yielding a Cambrian virtual geomagnetic pole (VGP) can be isolated.

Cambrian gabbros, basaltic and ultramafic rocks east of Zeehan and along the Murchison Highway give a VGP on the Ordovician segment of the polar wander path. If this reflects an overprint episode or drift and subsequent collision of a crustal segment with Australia, is at this stage unclear.

Cambrian volcanics along Jukes Road have been thoroughly overprinted presumably during the early Carboniferous.

The Meredith Adamellite appears to possess its primary magnetisation and plots on the early Carboniferous segment of the Australian polar wander path.

The Mesozoic basalts from Cape Portland possess too short a cooling history to ever have averaged out the effects of secular variation.

Our study was successful in evaluating the suitability of various Tasmanian Palaeozoic rocks for palaeomagnetic research. The quantity of material available and analysed is, however, insufficient to yield enough data to unequivocally establish representative VGP's for the rock units in question. It is recommended to continue this research and to add additional measurements to the ones presented by this report.

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I INTRODUCTION

The paleomagnetic record of selected Tasmanian rock formations has been studied within the framework of a collaborative program of the Department of Mines of Tasmania and BGR. The field work was undertaken in February 1989. The paleomagnetic measurements started in June 1989 and were completed in August 1991. All laboratory work was carried out in the Laboratory for Palaeomagnetic Research of the State Geological Survey of Lower Saxony in Grubenhagen (Lower Saxony).

This work is also considered as a complimentary part of the current geoscientific research activities of BGR in North Victoria Land, Antarctica. Both territories were joined together in the geologic past and have therefore been exposed to similar geologic processes before the breakup of the Antarctic and Australian land masses during the Cretaceous.

II PURPOSE OF STUDY

Only few paleomagnetic investigations have been carried out so far in Tasmania (see e.g. review paper by Embleton,1981). The principal difficulty lies in the structural complexity of the island and the difficulty to find suitable rock formations that have not or only to a minor degree been displaced or deformed throughout their geologic history. Prior to field work, a number of potential rock formations that might suit the above requirements were suggested by Dr. Findlay, Department of Mines.

The aim of this study was twofold:

- to search for material from selected Tasmanian rock formations suitable for paleomagnetic investigations
- to search for evidence for a suspected lateral displacement of segments of the early Paleozoic Tasmanian basement.

It is further hoped that the results of the project might serve as a useful guidance for future paleomagnetic investigations in the area.

III FIELD WORK

The following rock formations were selected for sampling:

- Cambrian volcanic rocks from the Smithton Trough area
- Cambrian basaltic and ultramafic rocks to the east of the Murchison Highway south of Renison Bell
- Cambrian Gabbros near Zeehan
- Cambrian feldspar-phyric volcanics along Jukes Road south of

Queenstown
- Devonian Meredith Adamellite Complex
- Devonian Granodiorite complex south of St. Helens
- Cretaceous dykes and lava flow at Cape Portland

The intention was to collect about 10 oriented hand samples from each region. Unfortunately, due to the insufficient rock exposure in various regions and the high degree of weathering in the western part of the country, this aim was not always attainable. The available samples are listed in Table 1.

Table 1

Sample numbers	Area
8900 - 8910	Smithton Trough
8911 - 8917	Murchison Highway
SH	" " (unoriented samples from two vertical bore holes)
8918 - 8921	Gabbros near Zeehan
8930 - 8940	Jukes Road
8942 - 8947	Meredith Adamellite
8950 - 8959	Granodiorite S of St. Helens
8960 - 8967	Dykes and lava flow at Cape Portland

In most cases oriented hand samples were taken in the field. In few instances, core specimens were drilled and their orientation marked in situ. The sampling localities are shown in Figure 1.

IV LABORATORY WORK

A number of specimens were cored from each hand sample. For this purpose, each hand sample was put in a gravel bed before coring and reoriented according to its orientation in the field.

The remanent magnetization of all specimens were measured on a spinner magnetometer. Subsequently, selected core specimens were demagnetized in steps of 5-20 Millitesla (mT) by the alternating field technique (af-demagnetization) and fewer specimens with a "Schoenstedt thermal demagnetizer" in steps of 50K or less. After each demagnetization step, the remaining magnetization of the specimens were measured again on a spinner magnetometer. Most of the sampled material turned out - as expected - to be only weakly magnetized. For this reason we were limited in the number of subsequent demagnetization steps. Beyond that limit, no meaningful result can be expected.

All measurements are summarized in part II of this report.

V RESULTS AND DISCUSSION

The measured magnetization directions as function of demagnetization are discussed below for each rock formation separately. The table below gives the average declination- and inclination values for N specimens from the location #, from where in each case one hand sample was taken. The a95-value represents the 95%-angle of confidence, which is a measure of the quality of the measured values given. The precision parameter K is also listed. K is a measure of the scatter of the vector directions measured from the samples of one site.

SMITHTON TROUGH

#	N	Decl.	Incl.	a95	K
8900	4	65.3	-66.1	65.6	2.9
8901	7	12.9	-68.1	26.2	6.3
8903*	10	3.7	-75.2	5.8	71.4
8903a	10	288.3	-69.8	7.3	44.7
8903b	8	259.5	-48.5	8.9	39.4
8904	4	28.7	-53.5	34.7	8.0
8905	4	355.3	-15.1	13.1	50.3
8906	4	64.7	-68.0	12.9	51.3
8907	4	346.3	-48.6	14.7	39.9
8908	4	17.2	-60.8	6.3	213.9
8909	9	273.0	-19.2	27.1	4.6
8910	4	5.7	-58.1	5.1	324.7

* 10 mT-field
8903a 20 mT-field (see text for discussion)
8903b 60 mT-field (see text for discussion)

With exception of locations 8905 and 8909, all measured inclinations are rather steep. The expected inclination for Cambrian rocks of Tasmania is shallower, since Tasmania was near the equator according to the various Gondwana configurations available. The large number of sites with rather steep I-values might have been exposed to a magnetic overprint, of which the mean declination (D_m) and mean inclination (I_m) was calculated by excluding 8905 and 8909 (see below). Location 8903 represents a special case. During af-demagnetization in fields up to 10 mT, a stable magnetization direction around D=4°, I=-75° was observed. In higher af-fields, the D-values turned toward W, I-values became shallower. Apparently, in af-fields of 15 and 20 mT a magnetization component was partly removed and a second magnetization direction started to emerge. For calculating D_m and I_m below, we have used the 10 mT-field-value.

Mean directions	D_m	I_m	a95	K
all except 8905, 8909	20.1	-64.9	10.6	28

Successive demagnetization of 8903 in steps up to 100 mT gave the following results:

af-field (mT)	N	D_m	I_m	a95	K
30	8	266.9	-65.8	17.9	10.5
40	8	268.8	-57.0	8.3	45.1
60	8	259.5	-48.5	8.9	39.4
80	8	251.3	-42.9	13.0	19.2
100	8	251.6	-41.9	18.4	10.0

The remaining magnetization of the samples beyond 100 mT is too weak to give meaningful results.

A virtual geomagnetic pole position at 84.0°E, 74.4°S for 8900-8910 (D_m=20.1°; I_m=-64.9°) has been calculated based on a mean position for all location sites at 145.12E, 41.00S (dp = 13.8°; dm = 17.7°; palaeolatitude = 46.9°S). The calculation of a VGP from one site (e.g. 8903 at high af-fields) would not be meaningful.

It should be noted that apart from the prevailent magnetization direction (see above) two more components appear to have survived in some samples. One component is characterized by I-values around -42° (palaeolatitude = 24°; see 8903) and the other one by I = -15° to -19° (sites 8905, 8909), being equivalent to a palaeolatitude of 8°-10°.

TRAMWAY

These locations to the east of the Murchison Highway are located along an old track of a tramway having linked in the past several mining operations in the area. The outcrops in the area with the exception of 8917 (fresh roadcut) suffer from deep weathering. The sampling was undertaken to test, if meaningful results can be obtained. The measured results by af-demagnetization are listed in the table below.

#	N	Decl.	Incl.	a95	K
8911	2	348.4	-67.5		
8912	2	336.0	-2.0		
8913	2	23.2	-66.1		
8915*	3	6.8	-46.0	29.7	18.3
8916	2	242.5	-5.6		
8917*	3	230.2	-6.3	24.0	27.4

* 8915 was stable in af-fields up to 100 mT. 8917 remained stable in af-fields up to 40 mT and showed then a systematic shift in higher fields toward D_m = 105° and I_m = 69° at 100 mT.

In addition, 2 specimens from each location were thermally demagnetized in successive temperature steps up to 680°C. The treatment had to be discontinued for 8911 at a temperature level of 400°C because of insufficient remaining magnetization of the specimens. These are the results:

#	N	Decl.	Incl.	Temperature-Range
8911	2	53.9	-67.2	0 - 250
8911	2	113.6	68.9	- 350
8912	2	329.3	19.1	- 680*
8913	2	25.3	-56.7	- 250
8915	2	28.3	-54.4	- 590
8915	2	52.8	-45.5	- 650
8917	2	235.9	3.6	- 620

* a secondary magnetization component was apparently removed at a temperature > 600°C

The results obtained by af- and thermal demagnetization are in reasonable agreement. Thermal demagnetization in the temperature range of 300 - 400 °C did reveal in the case of 8911 a second component of magnetization, whose significance is not clear. Since the sample - due to its weak magnetization - cannot be demagnetized above 400°C, it is not possible to confirm the true direction of this magnetization component.

The results of the af- and thermal demagnetization for each sample were combined. The following mean orientationes were obtained:

#	N	Decl.	Incl.	a95	K
8911	4	17.8	-69.9	19.6	23.0
8912	4	332.6	8.4	17.6	28.2
8913	4	24.3	-61.5	9.5	94.9
8915*	5	15.9	-49.6	16.1	23.4
8916**	2	242.5	-5.6		
8917	4	232.5	-2.4	12.7	37.3

* data taken for T = 560°C
** no thermal demagnetization data available

Two main magnetization directions can be observed:

a) 8911, 8913, 8915
b) 8912, 8916, 8917

For both sets the following mean directions can be calculated:

	D_m	I_m	a95
Mean directions for a):	19.1	-60.4	15.7
Mean directions for b):	212.1	-7.1	***

(*** angle of confidence > 90°; not defined)

8912 appears to have been rotated in the horizontal plane. The calculated mean direction b) is probably not representative.

Virtual pole positions based on a mean position of the location sites at 145.5°E, 41.8°S are calculated for a) as 60.1°E, 75.7°S (dp = 18.5°; dm = 24.3°; palaeolatitude = 41.4°S).

In addition, cores from two vertical drill holes were available for analysis. The core from one hole consisting of serpentinite proved to be too weakly magnetized to yield meaningful results. The other core consisting of basalt did give the following inclination values:

Sample	NRM	2.5mT	5mT	7.5mT	10mT
SH1	20.0		1.5		-4.5
SH2	-15.9	-11.1	-9.3	-8.5	-5.8

Declination values remained stable throughout the successive demagnetization steps. The basaltic layer in question (Cambrian age), being drilled from below the weathering layer, appears to be suitable for palaeomagnetic investigations. A palaeolatitude of 3° is suggested from the obtained I-values.

TRIAL HARBOUR

The result of the af-demagnetization measurements up to 40 mT are shown below:

#	N	Decl.	Incl.	a95	K	dp	dm
8918	4	49.6	24.6	18.0	26.9	9.3	20.0
8919	4	6.4	-77.4	10.5	77.0	7.0	17.3
8920	3	173.1	4.6	40.1	10.5	23.0	79.3
8921	4	217.5	-1.3	11.2	68.3	7.7	19.7

All samples with the exception of 8919 show the expected low inclination of Cambrian material. The anomalously high inclination of 8919 is indicative of an overprint, which we were unable to remove. Since the measured orientation is typical for Devonian material, we suspect that a Devonian intrusion near the collecting site has caused this overprint.

The declination value of 8918 deviates significantly from the expexted southerly direction. In addition the polarity of the samples are reversed. Therefore, also thermal demagnetization was carried out.

#	N	Decl.	Incl.	Temperature
8918	2	294.7	5.6	650°C

The specimens showed during the demagnetization unstable behaviour. The orientation as obtained by af-demagnetization was never obtained. For this reason, this sample is excluded from further discussion.

We are left with four samples which show shallow magnetic inclination:

#	N	Decl.	Incl.
8920	3	173.1	4.6
8921	4	217.5	-1.3

and in addition from the TRAMWAY locations

8916	2	242.5	-5.6
8917	5	232.5	-2.4

From these four samples a mean direction is obtained at:

D_m = 217.1 I_m = -1.3 a95 = 36.8

from which a virtual geomagnetic pole position (mean position of sampling locations at 145.33°E, 41.83°S) at 193.5°E, 36.0°N (dp = 18.4°; dm = 36.8°; palaeolatitude = 0.6°S) is obtained.

JUKE'S ROAD

Cambrian volcanics were collected along Jukes road. The volcanics show evidence of folding. It was therefore expected that the primary magnetization in the material, assuming, it had survived later deformational and tectonic phases, should scatter significantly. The measured orientations are summed up below:

#	N	Decl.	Incl.	a95	K
8930	4	316.3	-78.2	9.8	89.4
8931	4	277.7	-41.7	28.9	11.1
8932	4	202.1	-85.1	11.5	65.3
8934	4	206.7	-74.9	11.3	67.1
8935	4	15.4	-83.5	15.1	37.8
8936	4	61.6	-80.2	8.1	128.4
8937	4	43.9	-84.5	4.8	368.5
8938	4	260.2	-80.2	9.4	97.1
8939	4	8.6	-66.9	15.8	35.0
8940	4	77.3	-81.9	8.6	116.4

The data can be further summarized as follows:

N	Decl.	Incl.	a95	K	dp	dm
10	307.7	-84.2	11.4	19.0	6.0	13.1

From this result, the virtual geomagnetic pole (based on a mean position of sampling locations at 145.5°E, 42.2°S) can be calculated at 157.3°E, 48.0°S (dp = 22.3°; dm = 22.5°; palaeolatitude = 79.9°S).

Selected specimens were also thermally demagnetized. The results are in good agreement with the available data from the af-demagnetization:

#	N	Decl.	Incl.	Temperature
8930	2	350.1	-70.4	- 350
8932	2	353.0	-86.3	- 350
8932	2	247.7	-3.0	- 650
8936*	2	64.1	-78.9	- 400

* Steep rise in susceptibility in both specimens at temperatures above 400oC (mineral phase change?)

in the case of 8932 it appears that the overprint was removed at temperatures above 350°C. The then obtained magnetization direction appears to reflect the orientation expected for Cambrian material. In that case, little or no deformation has affected the sample after imprint of this magnetization component.

MEREDITH ADAMELLITE

This complex has been dated by the Rb-Sr-method at 353 +-7 m.y. (Department of Mines, base map of Tasmania, 1976). Steep inclination values were therefore expected:

#	N	Decl.	Incl.	a95	K
8942	4	265.1	9.4	14.4	41.6
8943	4	308.2	-76.9	7.4	155.3
8945	11	35.7	-81.5	5.2	77.8
8946	4	265.7	-80.4	13.1	50.5
8947	6	22.8	-70.1	15.4	19.8

8942 appears to be anomalous in comparison to the rest of the samples. The specimen was possibly not in situ. Based on the rest of the samples the following mean declination and inclination values were obtained:

Decl.	Incl.	a95	K
347.3	-81.5	14.0	43.9

A virtual geomagnetic pole (based on a mean position of sampling locations at 145.07°E, 40.5°S) was arrived at 151.5°E, 56.6°S (dp = 26.7°; dm = 27.5°; palaeolatitude = 73.4°S).

ST. HELENS

The material from the Devonian granodiorite complex south of St. Helens proved to be unsuitable for palaeomagnetic investigations. The large dispersal of measured values preclude the determination of representative mean values for declination and inclination of the remanent magnetization of this material.

CAPE PORTLAND

Lamprophyre dykes and andesitic flows were emplaced during the Cretaceous in the Cape Portland area (Jennings & Sutherland, 1969). Hornblende minerals of both suits have yielded K/Ar-ages between 101 - 102 Ma (McClenaghan et al., 1982). Several dykes (#8960-#8964) and one flow (#8965-#8967) near the NE-tip of Tasmania have been sampled and analysed.

#	N	Decl.	Incl.	a95	K
8960	4	47.8	-55.0	14.6	40.6
8961	4	15.6	-65.6	5.6	274.8
8962	4	18.7	-79.1	2.6	1211.6
8963	4	34.0	-72.8	3.1	882.1
8964	4	301.9	-76.3	7.3	160.7
8965	4	260.5	+16.1	42.9	5.5
8966	4	23.8	-72.9	13.4	48.2
8967	4	7.1	-68.3	6.1	224.6

With the exception of two sites a tight grouping of the measured remanent magnetization directions of each site is observed as expected for this type of material. 8965 shows large internal scatter in the magnetization directions. The resultant D- and I-values are alltogether unrealistic. 8965 was excluded from further consideration. Also 8960 seems to be affected by a unremoved secondary component as can be seen from the (for this type of material) rather low K-value and the surprisingly low inclination angle.

Combining the remaining sites we arrive at

N	Dm	Im	a95	K	dp	dm
6	10.6	-74.3	8.2	68.1	13.2	14.8

VI INTERPRETATION

The correlation between the calculated VGP's and the apparent polar wander path (APWP) of Australia is considered first. The VGP's available from this study are summarized below:

Locality	VGP	
Smithton Trough:	84.0°E, 74.4°S	
Trial Harbour:	193.5°E, 36.0°N	(13.5°E, 36.0°S)
Juke's Road:	157.3°E, 48.0°S	
Meredith Adamellite:	151.5°E, 56.6°S	

The Australian APWP (or alternatively of Gondwana) for the Palaeozoic has been a matter of debate for some time. Principally, two alternative paths have been proposed:

a) direct migration of the pole from Northern Africa (Ordovician position) to central Antarctica (Devonian postion). This path (Figure 2) was proposed in detail among others by Thompson & Clark (1982).
b) large excursion of the pole from North Africa via South America (Silurian position) to central Antarctica. Convincing evidence supporting latter path (Figure 3, adapted from Embleton, 1981) was presented by van der Voo (1988). We have chosen latter path as base of the interpretation of our data.

The above listed VGP from the Cambrian Smithton Trough Volcanics corresponds well with the published VGP of the Devonian (375 m.y.) Housetop Granite (Briden, 1967) at 94°E, 67°S indicating a magnetic overprint of the Smithton Volcanics by neighboring Mid-Palaeozoic granite complexes.

Specimens from two sites (8905, 8909) give both low inclination values, but differ substantially in their declination values. This could be due to a number of possible factors (site not in-situ, several inseparable magnetization components present,..). No further interpretation for these anomalous sites is offered.

Site 8903 shows a strong secondary component stable up to high af-fields. No other sites with a comparable magnetization direction have been found. Nevertheless, this one site has yielded a) the overprint signal (in af-fields up to 20mT) and b) the expected D- and I-values for Cambrian material. A VGP calculated from this one site (16.1°E, 11.7°N) lies exactly on the Cambrian portion of the Australian APWP. If this is a fortuitous coincidence or not is not clear. We take this result as a likely indication that the primary magnetization has survived in a small portion of the Smithton Volcanics exposed

today. If this interpretation is correct, then there is little room for any speculation of the Smithton Volcanics being part of an allochthonous crustal segment.

Two Tramway-sites and two Trial Harbour-sites show consistently low I_m-values and D_m-values of S to SW-directions. The calculated VGP based on these four sites compares rather well with the VGP of the Upper Cambrian Dundas Group at 13°E, 23°S (Giddings & Embleton, 1974). It must be stressed however that the available number of sites is insufficient to clearly establish a representative VGP for the sites in question.

The rest of the investigated Tramway and Trial Harbour sites were clearly affected by a Mid-Palaeozoic magnetic overprint. The material from site 8918 behaved in an odd fashion. The results obtained by successive af- and thermal demagnetization differed substantially for unknown reasons. The site was excluded from further consideration.

Our preliminary VGP for the Trial Harbour material as well as the published VGP by Giddings & Embleton lie on the Ordovician portion of the APWP. If this is evidence of continental drift of the Cambrian basement of Tasmania versus Australia or the result of incomplete averaging of the paleomagnetic record, is not clear at this stage. Theoretically, a drift episode would imply movement of Tasmanian basement roughly along the coast of Victoria Land/Antarctica and eventually collision with Australia. If we accept the concept by Dalziel (1991) of an Eocambrian supercontinent juxtraposing North America next to Victoria Land/Antarctica and Australia until Late Cambrian, than any drift episode would have to occur during the early Ordovician.

As already discussed, the material from the Juke's Road sites has been magnetically overprinted after a phase of intensive deformation. The VGP, we obtained on the basis of 10 sites, represents therefore the episode of overprint. Our VGP lies near the Cretaceous or Upper Carboniferous segment of the Australian APWP (see Fig. 4; the Australian APWP for both geologic periods overlaps.) In which time period the overprint occurred, cannot be resolved on the basis of our data.

The VGP of the 350 m.y. old (early Carboniferous, according to Harland et al., 1990) Meredith Adamellite is located on the Lower Carboniferous portion of the Australian APWP (Figure 3). The VGP obtained by this study could theoretically also represent an Cretaceous overprint event (Fig. 4). The presence of the primary magnetization component is however considered more likely, since no obvious evidence for an overprint was found. The available number of sites is insufficient to define a truly representative VGP for this Adamellite complex. Additional suitable material is needed to establish that position.

The palaeomagnetic record of the material from Cape Portland taken from the only dm-wide dykes and one rather thin flow should

reflect the geomagnetic field orientation from only a very short time span to be measured in hours or days. An averaging out of the secular variation of the geomagnetic field is not to be expected. The thight grouping of all measured D- and I-values around the mean might actually be an indication that the andesitic flow and the dykes were emplaced within a very short time span or maybe even at the same time.

Correspondingly, the VGP that follows from above data (133.3°E and 69.1°S, assuming a common sampling location at 147°,55'E and 40°,45'S) is located far off the accepted pole position for the Cretaceous period and most likely reflects incomplete averaging.

VII RECOMMENDATIONS

A complex magnetic overprint history masks the primary magnetization of most selected Tasmanian Palaeozoic rock units, as the above survey has shown again. The most influential overprint event seems to have occurred during Devonian to Carboniferous times. A second difficulty in obtaining the primary magnetization lies in the lack of availability of sufficiently unweathered material in the field.

To obtain soundly based palaeomagnetic data on the character of the Tasmanian basement and its tectonic evolution, the determination of the primary components of Cambrian rock units is a prerequisite. To overcome the existing obstacles in identifying these components, two principle approaches are available:

1) The systematic sampling of a very large number of sites might yield sufficient material which still carries a sufficiently strong primary magnetization component such as 8903. The availability of enough suitable surface exposures in the field is however questionable.

2) Probably more promising would be a drilling program to recover oriented drill cores from below the weathering zone. A drilling program would first of all alleviate the surface exposure problem. In addition, the question of the site being in situ or not can be resolved on the basis of a 10 - 20 m long core more easily than by mere judgement of the visible surface exposure. Based on the results of the Trial Harbour sites and SH1/SH2, the Cambrian gabbros and associated rock units are in my judgement the most promising target area in this respect.

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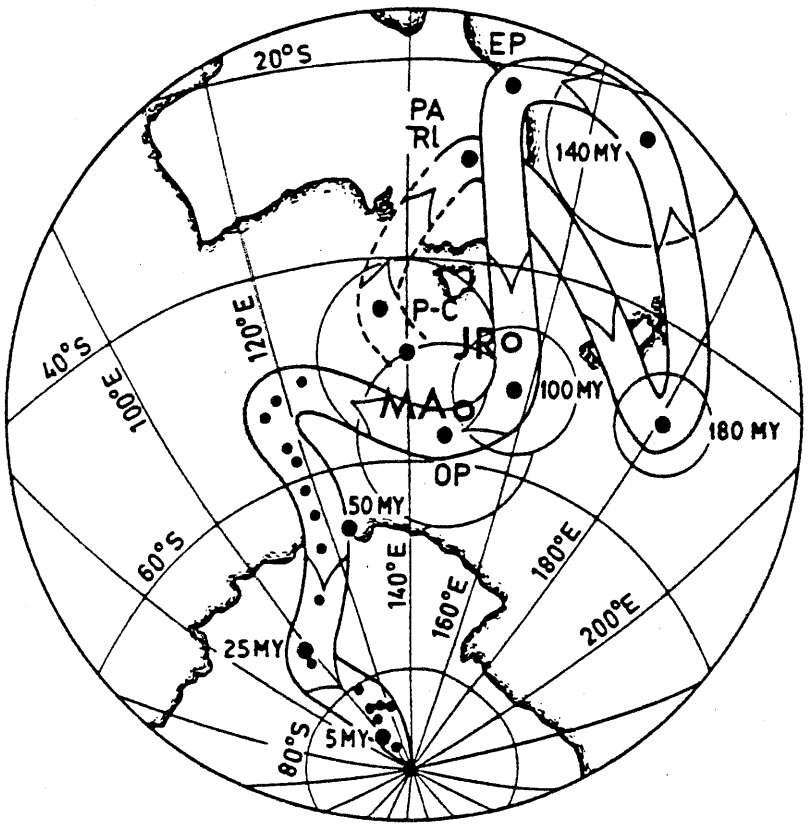

Figure 4: Mesozoic and Cenozoic APWP for Australia (taken from Embleton, 1981).
MA = Meredith Adamellite
JR = Juke's Road

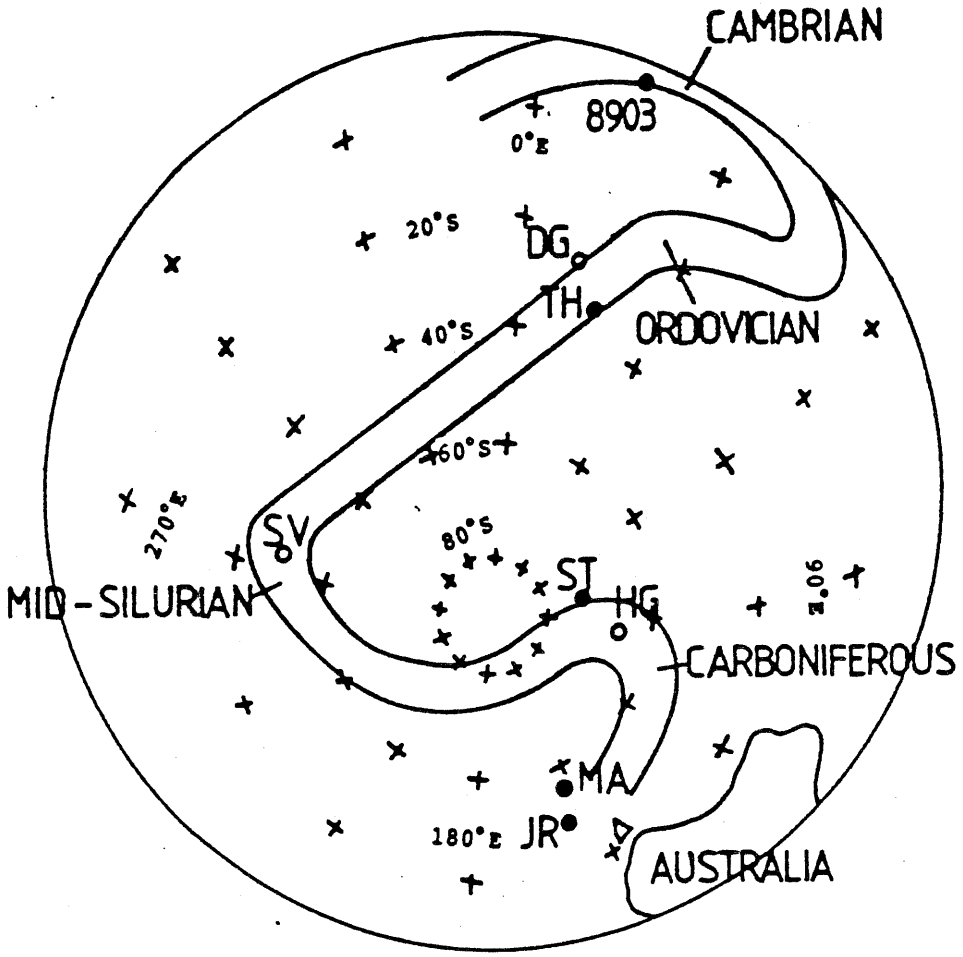

Figure 3: APWP for Australia (modified after Embleton, 1981 and Van der Voo, 1988)
DG = Dundas Group (see Embleton, 1981)
TH = Trial Harbour
SV = Silurian Volcanics (see Embleton, 1981)
ST = Smithton Trough
HG = Housetop Granite (see Embleton, 1981)
MA = Meredith Adamellite
JR = Juke's Road

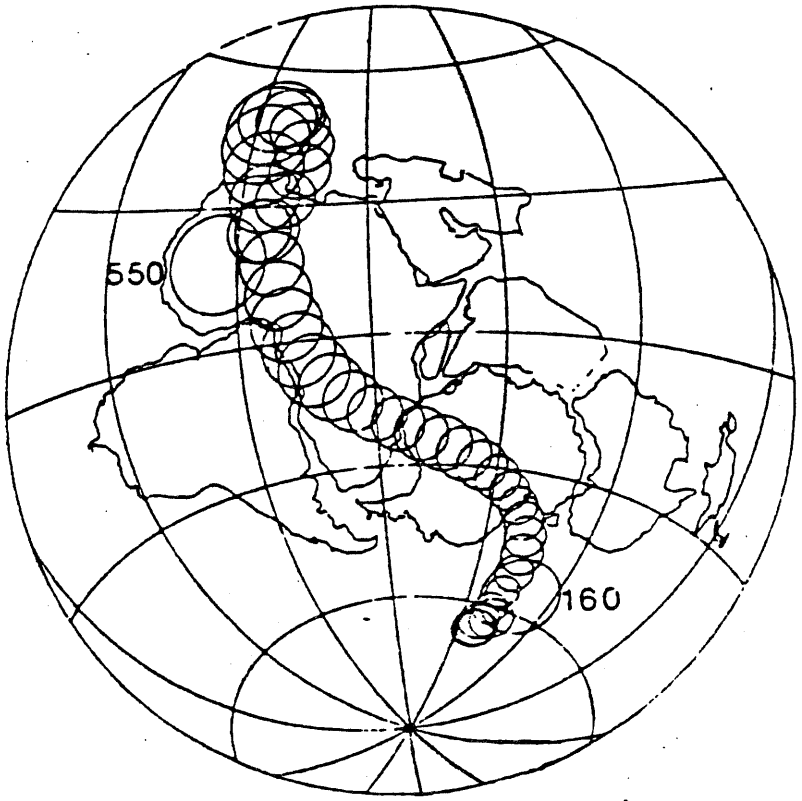

Figure 2: 95% confidence limits for the apparent polar wander path (APWP) of Gondwana drawn at 10-Ma intervals (taken from Thompson & Clark, 1982)

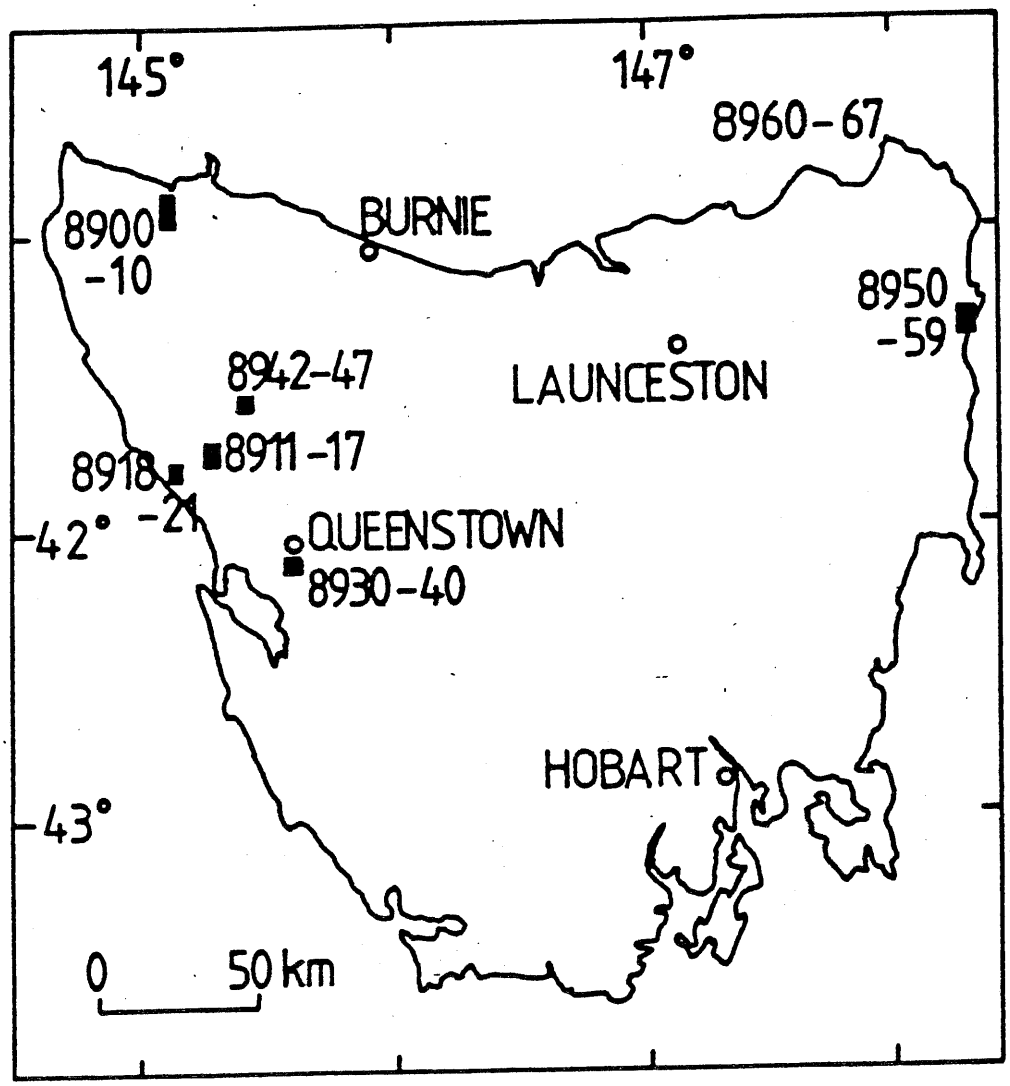

Figure 1: Map of sampling localities